

## Micro tools

### TECHNICAL FIELD

This invention concerns micro-surgical tools that can be delivered ~~through or by~~ a catheter or needle. These tools or micro-structures can be used to adapt, assemble, separate, fortify, dilate, close and hold biological structures inside the body during and after surgery. The tools may be stents, valves, clips, nets, knives, scissors, dilators, clamps, tweezers etc.

### Introduction BACKGROUND OF THE INVENTION

The use of microstructures to assemble, fortify or dilate biological structures inside the body during and after surgery can help the surgeon in a number of ways. The operation of electrically actuated tools can help the surgeon to simultaneously position, operate manually, and observe. By positioning the tool by hand and separately operating the tool ~~it~~ through external controls (i.e. footswitch, voice control, other software-control) a much higher degree of precision is achieved ~~expected~~. In microsurgery, this is ~~an~~ especially desired advantage.

The development of microactuators has been spurred on by the desire to be able to use tools beforehand or during invasive surgical procedures. Because tools may be used for cutting, drilling, holding, dilating, suturing, adapting or supporting, the tools must have specific size and shape. For example, a certain tool might be needed during a surgery and the only way to introduce this tool is to place it inside a catheter or needle. Thus, the tool must be designed within the specific dimension of the catheter or needle.

~~To be able to apply, beforehand or during an invasive procedure, a tool of a required size and geometry designed for the purpose of cutting, drilling, holding, dilating, suturing, adapting or supporting from tools that, for example, could be introduced through, placed inside or located at the end of a catheter or needle, is another desired function, requiring development of microactuators.~~

~~The application of structures in or introduced through a catheter or needle is of particular interest~~

~~[[at]] and more specifically the application of tools, which are to be left at the site after insertion, and which have to execute their function for some limited time duration. The A first example here is that of clips for surgery, which are sub millimeter to millimeter structures, which would be used to hold two separated biological structures joined, for example during a healing period (Fig. 1A-1C).~~

~~Another example is a that of structure[[s]] for controlling the flow through blood vessels. The simplest level example is that of a clip used to prevent blood flow to a biological structure downstream in the blood flow. Such a clip, or series of clips, would be mounted and left to hold a firm grip on the blood vessel and thus to prevent the flow of blood. In Figure 2 is shown a series of structures suitable for constricting blood vessels.~~

~~The third example is [[at a]] somewhat more complex level with structures built [[in]] with a geometry where they could be used inside or outside tube like structures, i.e. as so-called stents to dilate a stenotic area or to internally or externally fortify or join the structure(s) (Figure 5A and 5B). Stents are of particular interest since they are to be inserted inside the tube, then to be left there to expand a stenotic (examples: blood vessel, biliary duct) or to fortify a weak (examples: blood vessel with aneurysm, divided biliary duct) part of a tubular structure~~

~~Arrays of fingers could be used to hold cylindrical objects, such as nerves and nerve fibers, or blood vessels. With the help of microactuators holding the structures (Fig. 3A-3D), adjacent microstructures can operate operating as neural sensing or activating electrodes, and will enable recording of signals from or to activate activating nerves. [[This]] Furthermore, they could be used as a synthetic neural connector, or bridging a severed nerve or nerve fiber.~~

~~Elements Tools with some temporary mechanical function could also be inserted in membranes (Fig. 4A-4C). Insertion devices of this kind with temporary mechanical functions could be used for mounting a hole through a membrane such as which commonly used in ear surgery for pressure equilibration. Making these tools as microdevices will [[much]] decrease the effort to place and~~

~~remove the inserted devices and to keep them in place during the desired time period.~~

~~Clips, stents, finger arrays and insertion devices, once applied, could be resorbable or permanent. They could express various degrees of stimulation of cell growth on its suites, various degrees of anti-thrombotic activity as well as different antibiotic activities. They can also be carriers of various biochemical or biological components.~~

The necessary elements to accomplish these functions are the electrochemically activated micromuseles microactuators, built by micromachining thin metal and polymer layers or only polymer layers. (Elisabeth Smela, Olle Inganäs and Ingemar Lundström: "Controlled Folding of Micron-size Structures", Science 268 (1995) pp.1735-1738) or only polymer layers. These microactuators can be produced in sizes from micrometers to centimeters, and operate well in biological fluids such as blood plasma, blood, buffer and urine. They are therefore suitable tools for micro invasive surgery inside the body. The versatility of construction and the speed of response, as well as the force of these microactuators render them as one of the best types of microactuators inside the body. An international patent covers one route of fabrication of such devices (A Elisabeth Smela, Olle Inganäs and Ingemar Lundström: "Methods for the fabrication of micromachined structures and micromachined structures manufactured using such methods", Swedish patent application number SE 9500849-6, March 10, 1995 in succession also a PCT and international patent).

#### Prior art

The combination of microactuators and catheters are not well documented in the literature. A ~~patent search reveals a few examples but none. No patents that describe[[s]] the use of~~ microactuators as tools housed inside a catheter; however several examples of microactuators used to position a catheter are to be found in the following patents:

US5771902 Micromachined actuators/sensors for intratubular positioning/steering  
US5519749 Microvalve  
WO9837S16A1 Microfabricated therapeutic actuators  
WO9739688A2 Method and apparatus for delivery of an appliance in a vessel  
WO9739674A1 Spring based multi-purpose medical instrument  
U55855565 Cardiovascular mechanically expanding catheter

Several mechanisms are suggested for the microactuators in these applications, found among shape memory alloys (including polymeric materials) and piezoelectric materials. The use of conjugated polymers in micromuscles is not documented for catheter tools.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the invention can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIGs. 1A-1C are a perspective view of the first embodiment of the present invention.

FIG. 2 is a perspective view of other tools in which microactuators are used.

FIGs. 3A-3B are a perspective view of the fifth embodiment of the present invention.

FIGs. 4A-4B are a perspective view of the sixth embodiment of the present invention.

FIGs. 5A-5B are a perspective view of the seventh embodiment of the present invention.

#### DETAILED DESCRIPTION OF INVENTION

Our novelty and innovation ~~therefore~~ resides in the use of microactuators based on conjugated polymers being electrically operated and mounted in or on a catheter or needle. These microactuators are [[to be]] positioned with the help of the catheter, and then activating the these microactuator structures are activated and carried on the needle. The microfabrication of such microactuators renders possible a number of geometries [[from]] and a size as small as 10  $\mu\text{m}$ , which is and larger, difficult to produce by mechanical production techniques. They may be produced by use of the method presented ~~in patent A above~~ U.S. Patent 5,771,902 and then mounted in or on the needle or catheter, or they might be produced by novel manufacturing

methods. With the ~~help of this invention, invention described therein,~~ completely novel microsurgery tools are now available.

The introduction of structures in or through a catheter or needle is of particular interest and more specifically the application of tools, which are to be left at the site after insertion, and which have to execute their function for some limited time duration. The production of individually actuated tool arrays render little difficulty beyond that of producing the individual tool. ~~we have to see that electrical~~ Electrical contacts ~~[[are]]~~ must be supplied to actuate each microactuator separately. This can be done by wiring the single microactuator to be used as the working electrode; the catheter is then used as the counterelectrode, and will ~~be able to supply all the charge that we ever need is needed~~ to actuate all those microactuators. As wires may easily be produced in width down to 10  $\mu\text{m}$  with photolithography or with soft lithography, ~~we will be able to put thus by putting down parallel conductor wires at least 50 microactuators at least may be placed~~ along the tool array located in/on a needle of 1 mm width, ~~with the simple philosophy of putting down parallel conductor wires.~~ Should ~~we need more~~ more wires be necessary, more elaborate addressing schemes might be ~~needed used~~.

~~Should a necessity for If a three electrode system[[s]] be found in any of the is necessary in any application[[s]], microfabricated reference electrodes or macrosize reference electrodes carried on the catheter housing offers a solution for this problem can be used as a third electrode.~~

A first embodiment of the present invention is clips used for surgery, which These clips are sub-millimeter to millimeter structures, used to hold two separated biological structures joined, for example during a healing period. FIG. 1A-1C shows an example of a clip tool in which microactuator may be used. Clips may be used in surgery to hold together two separate biological structures. FIG. 1A - FIG. 1B show a clip 1 before and after it is used to join the open structure 2 to hold it closed. The clip 1 is attached to second clip 4 and a chain of clips 5 that are confined by a cylindrical housing 3, as shown in FIG. 1C. The cylindrical housing 3 may be catheter or a needle.

Another embodiment is a structure for controlling the flow through blood vessels. The simplest level example is that of a clip used to prevent blood flow to a biological structure downstream in the blood vessel. Such a clip, or series of clips, would be mounted and left to hold a firm grip on the blood vessel and thus to prevent the flow of blood. In Figure 2 is shown a series of structures suitable for constricting blood vessels. Should the tool arrays be collectively addressed~~This array of tools may only be collectively addressed~~, and the tool array is designed to set free the outermost clip, on actuation of the all the clips 5, we will need a mechanism of confining the movements of all but the outermost clip 1 is needed. This is done by assembling the clip array 5 into a cylindrical housing 3, preferably [[the]] a catheter, prior to insertion in the body. The cylindrical housing 3 is now confining confines the motion of microactuators, which search in vain to expand the strong metal casing on operation. When the outermost clip [[C1]] 1 is actuated, the clip is opened; likewise is the next-to-the outermost clip [[C2]] 4 partially free to move as it is protruding outside the cylindrical housing. Therefore the partial opening of [[C2]] the next-to-the outermost clip 4 sets [[C1]] the outermost clip 1 free, as well as opens it up for subsequent spontaneous closing on the site to be clipped.

#### Figure captions

Figure 1A—1C shows clips and dip arrays, where the clips are mounted in sequence, and area confined by a cylindrical housing, and where the activation of the outer most clip C1, opening up The clip to join the open structure W1, and then being set free by the simultaneous operation of C2, so as to be left at the structure W1, holding the structures together.

Figure 2 shows tubular tweezers 100, tweezers 110 and knives 120, based on microactuators. The indicated movement is driven by microactuators properly mounted and designed. The tools are housed in a cylindrical housing 140, which, for example, may be a needle or a catheter.

Figure 3A - 3B show[[s]] a fifth embodiment 230 of the present invention. Arrays of fingers could

be used to hold cylindrical objects, such as nerves and nerve fibers, or blood vessels. With the help of microactuators holding the structures (Fig. 3A - 3D), adjacent microstructures can operate as neural sensing or activating electrodes, and will enable recording of signals from or to activate activating nerves. Furthermore, they could be used as a synthetic neural connector, or bridging a severed nerve or nerve fiber. A [[a]] neural connector 230, [[where]] with a number of small fingers 220 coil around [[a]] two cylindrical nerves 200, 210 to make a tight tightly hold the nerve 240. Two separate nerves 200, 210 are here joined with the help of a common neural connector 230. This procedure is used to which would be desired for accomplishing regrowth [[of]] the nerves. In addition, small electrodes (not shown) can be fashioned along with the microfingers 220, and be used to sense or excite nerve signals.

Tools with some temporary mechanical function could also be inserted in membranes (Fig. 4A - 4C). Insertion devices with temporary mechanical functions could be used for mounting a hole through a membrane commonly used in ear surgery for pressure equilibration. Making these tools as microdevices will decrease the effort to place and remove the inserted devices and to keep them in place during the desired time period. Figure 4A - 4C show a sixth embodiment 300 of the present invention. An insertion device 330, for making a temporally hole in a membrane 320 permanent hole through a membrane. The device is housed in a catheter/cannula/needle 310 and is inserted through the membrane 320 so as to make the device 330 form a hole 350 through the membrane.

Figure 5A - 5B show a stent device. The seventh embodiment 400 is somewhat more complex with structures built with a geometry where they could be used inside or outside tube-like structures 410, i.e. stents 420 to dilate a stenotic area 430 or to internally or externally fortify or join the structure(s) (Figure 5A and 5B). Stents 420 are of particular interest since they are inserted inside the tube 410, then they are left there to expand a stenotic (examples: blood vessel, biliary duct) or to fortify a weak (examples: blood vessel with aneurysm, divided biliary duct) part of a tubular structure 430 (FIG. 5B).

Clips, stents, finger arrays and insertion devices, once applied, could be reabsorbed or be

permanent. They could express various degrees of stimulation of cell growth on its surfaces, various degrees of anti-thrombotic activity, as well as different antibiotic activities. They can also be carriers of various biochemical or biological components.

It should be emphasized that the above-described embodiments of the present invention are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the invention. Many variations and modifications may be made to the above-described embodiment(s) of the invention without departing substantially from the spirit and principles of the invention. All such modifications and variations are intended to be included herein within the scope of this disclosure and the present invention and protected by the following claims.

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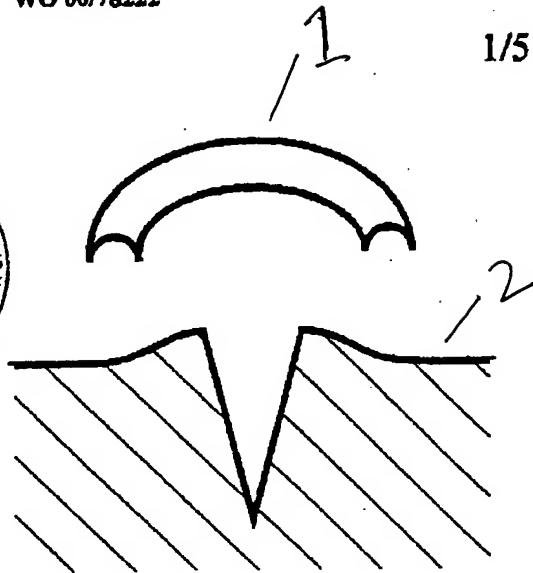


Fig 1a

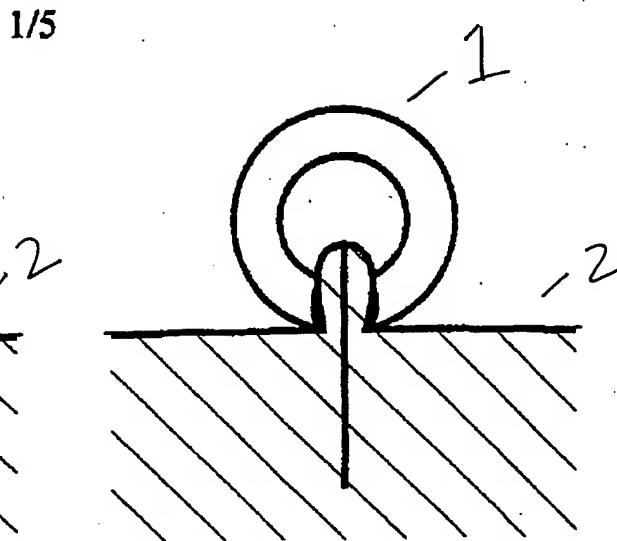


Fig 1b

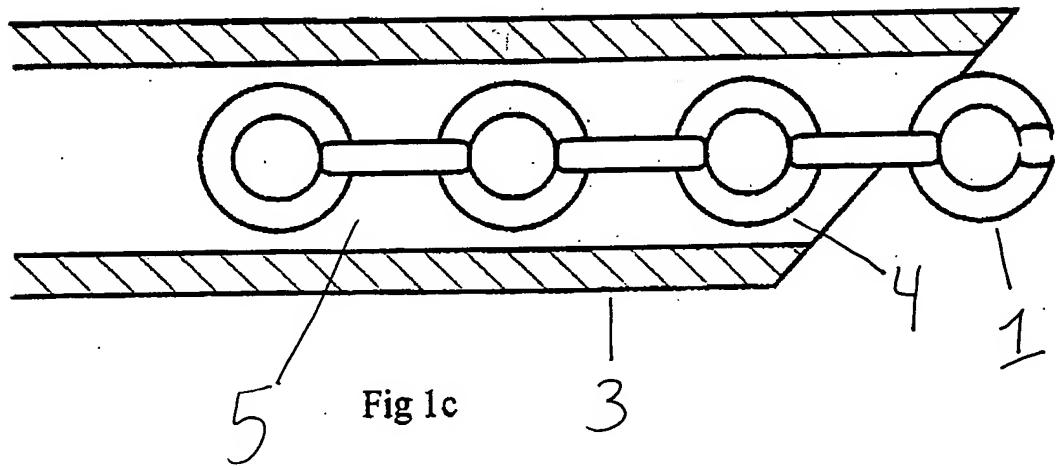
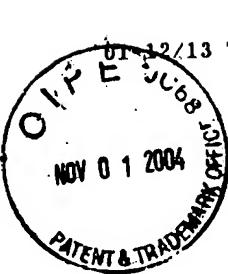


Fig 1c



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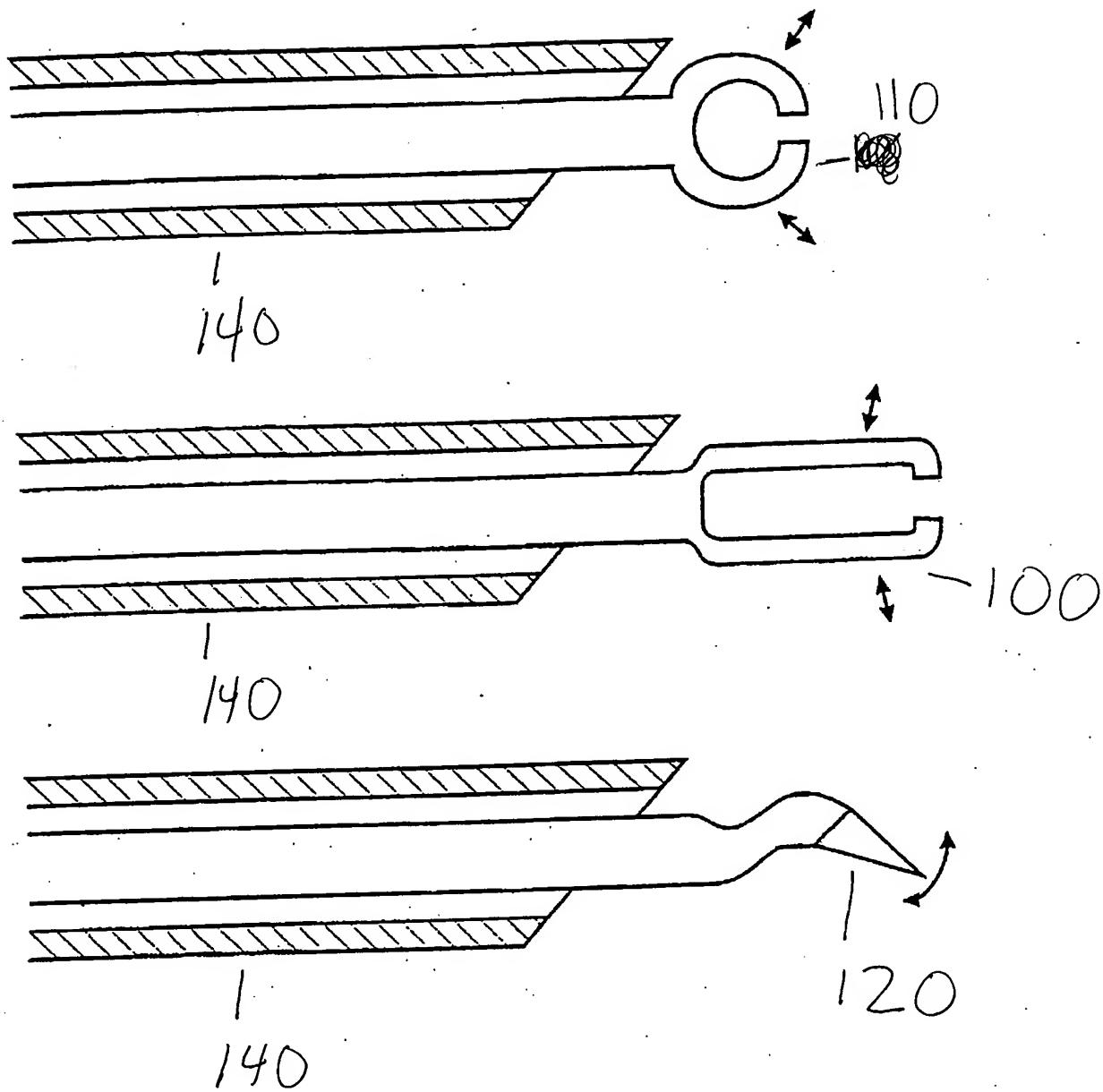


Fig 2

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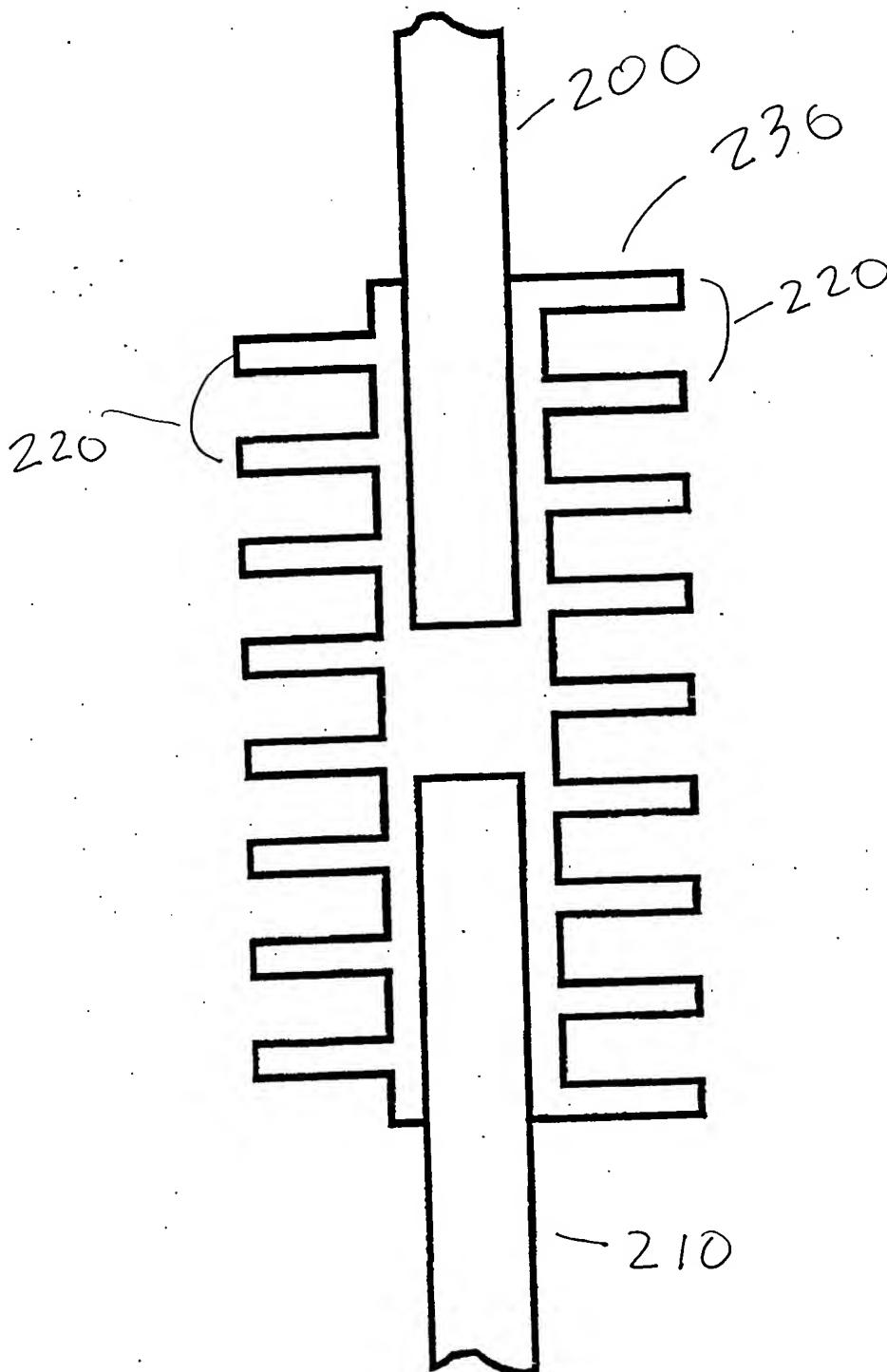


Fig. 3A

Fig. 3a och 3b

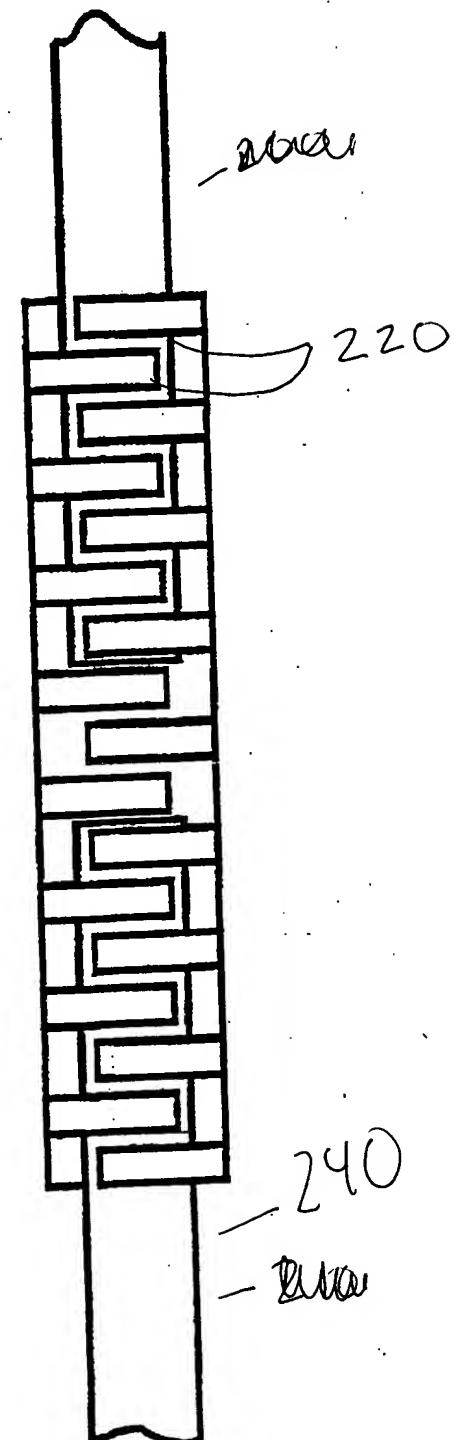


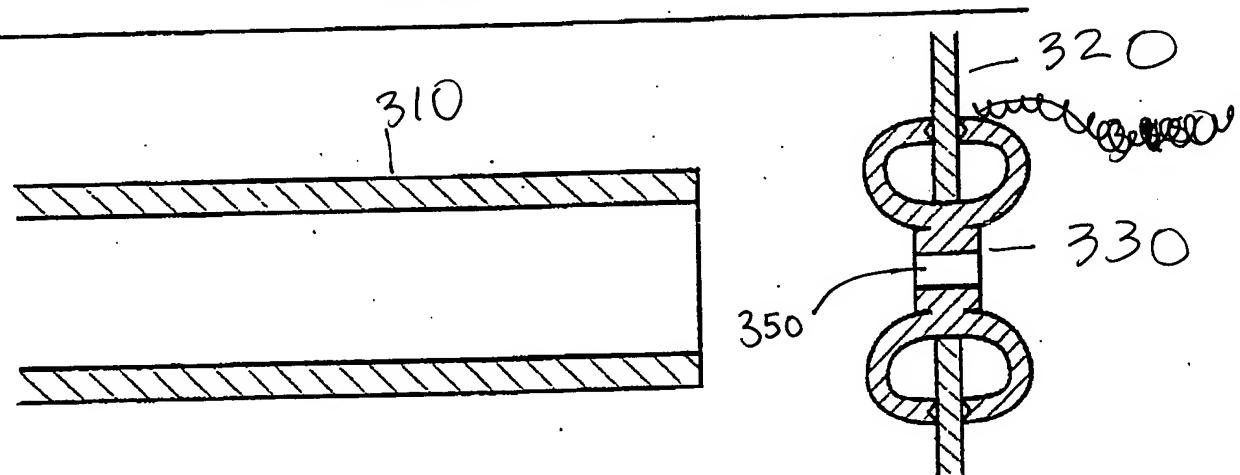
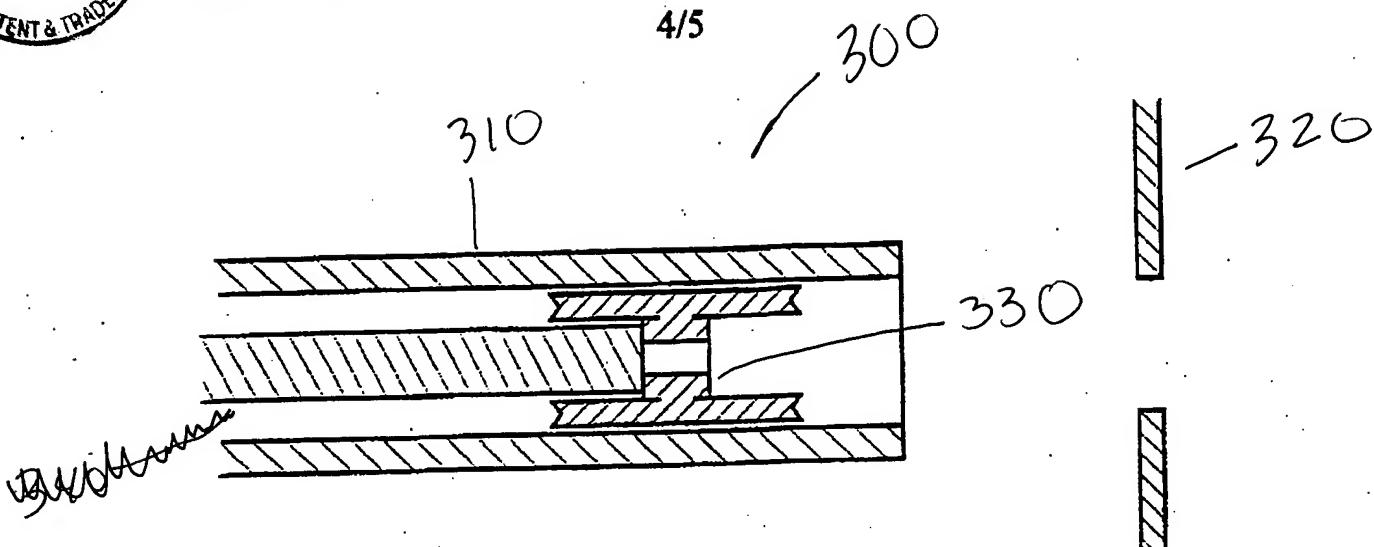
Fig. 3B

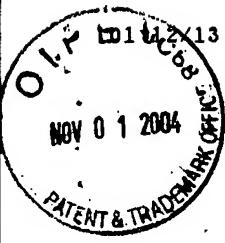


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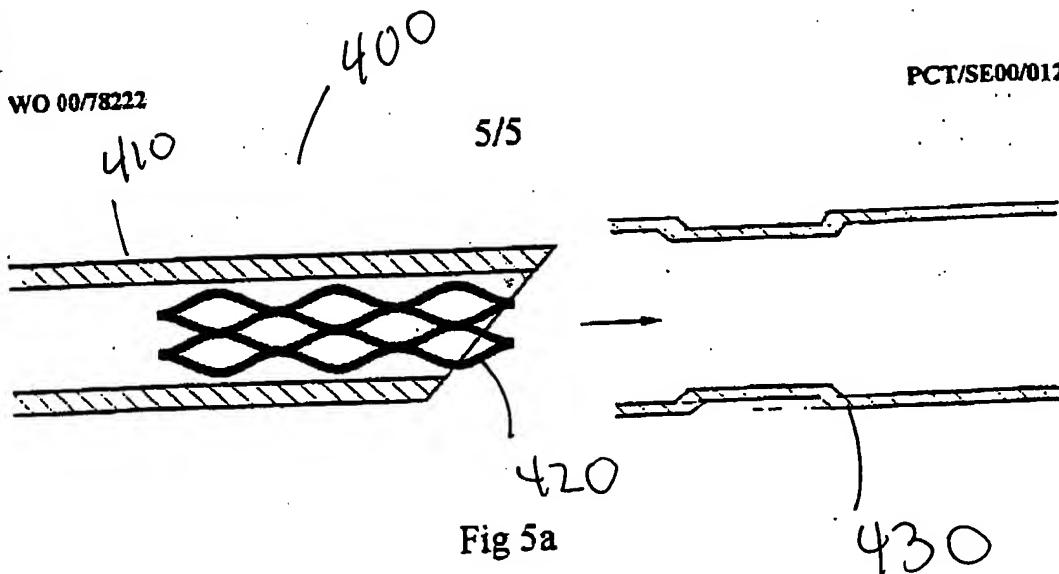


Fig 5a

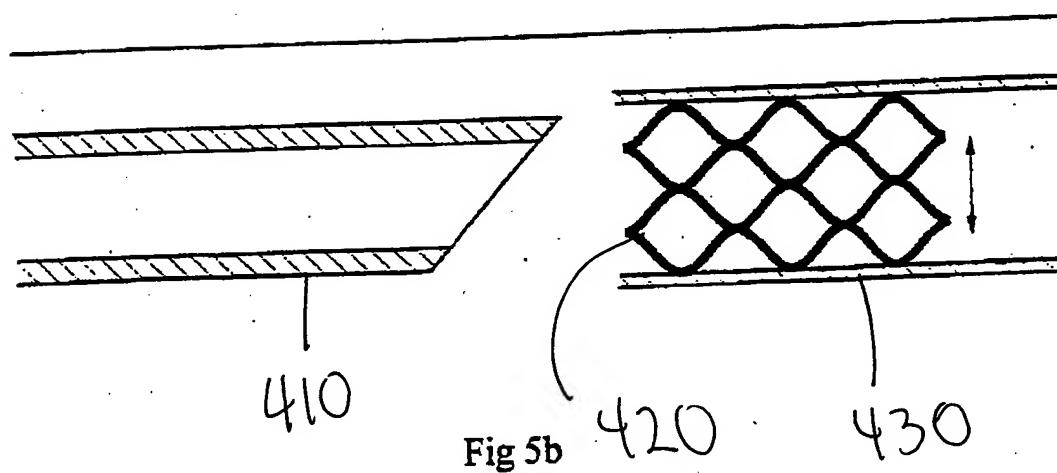


Fig 5b